

HVPE REGROWTH ON FREE-STANDING GaN QUASI-SUBSTRATES

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The size enlargement of bulk GaN crystals, as e.g. obtained from melt solution at high pressure or by sublimation technique, remains one of the biggest unsolved problems in the GaN field. The hydride vapour phase epitaxy (HVPE) method is a promising approach for growing thick GaN films of good crystalline quality and low defect density over a 2"-wafers, which is an important advantage since the internal defects can propagate into the subsequently grown structure. The HVPE together with the recently developed laser-induced lift-off separation technique [1] may enable large area good quality free-standing substrate material. However due to the use of large lattice mismatched sapphire substrates, crack appearance in thick layers is a big obstacle. Depending on growth and cooling conditions, the critical thickness for crack appearance can be increased, for instance, using reactively sputtered high temperature AlN buffers we succeeded in growing 45- μm -thick crack-free layers [2], and also crack-free 74- μm -thick films have been achieved utilising ZnO buffer [3]. However, this is still not sufficient for normal handling during substrate separation and pregrowth preparation. Another solution to grow thick crack-free films may be the use of lateral overgrowth techniques, although they require a complicated multistep procedure suffering of reproducibility difficulties. An alternative for growing thick crack-free GaN substrates is HVPE-GaN layers separated from the sapphire with subsequent HVPE strain-free homoepitaxial regrowth up to 200-300 μm thickness.

In this work, we report on the preparation and the HVPE regrowth of thick GaN films as well as on the properties of the regrown films. The HVPE-GaN films were initially grown either directly on sapphire or using a 2- μm -thick undoped or a Si-doped MOCVD template, or using reactively sputtered high-temperature AlN buffer. The details of this growth and the physical properties of such HVPE thick GaN layers have been reported elsewhere [2]. These thick crack-free GaN films with a thickness in the range of 20-50 μm were separated from the sapphire substrates by a lift-off process. The third harmonic of Q-switched YAG:Nd laser has been utilised for delamination free-standing GaN films. We found that a highly defective interface region localised in a very thin sublayer close to the sapphire is the key for a successful delamination. The thin defective layer absorbs more efficiently the laser power and it leads to a uniform thermal decomposition of this interface region. The effect of nucleation structure of the thick GaN film and/or of the buffers on both the separation process and the damaged superficial interface will be discussed based on transmission electron microscopy imaging data. After chemical treatment, the free-standing films have been regrown on the Ga-face. Quasi-bulk GaN substrates, having a current maximum size up to 250- μm -thickness and 10x10 mm area, were obtained by HVPE regrowth on free-standing HVPE-GaN films.

A photoluminescence spectrum of an as-grown 40- μm -thick GaN layer on sapphire together with a spectrum of the same film after separation and two spectra of the same regrown free-standing GaN film (up to thicknesses of 100 μm and 200 μm) are shown in Fig.1. As can be seen the narrow (~ 2 meV) exciton peaks in the spectrum of the as-grown film are fully reproduced in the regrown films indicating their good crystalline quality. Surprisingly, there is no essential shift of the donor-bound exciton (DX) peak of the as-grown film with respect to that of the separated and the regrown films. Such shift would be expected if the main stress in the as-grown films is due to substrate-induced compressive strain and its absence here evidences a relaxation present in the thick (more than 20 μm) films even before the lift-off. However, there is a small shift of about 3 meV in all samples studied with respect to the energy position (3.471 eV [4]) line of the bulk strain-free material. Therefore, we tentatively attribute the residual stress in our layers to the dislocation-related inhomogeneously distributed stress along the growth axis in the thick GaN layers. Since the regrown layers replicate mainly the defect distribution character and crystal quality of the underlying film, the stress persists in the overgrown films.

High resolution x-ray diffraction and Raman scattering measurements were used to study in a comparative way the structural properties of the free-standing regrown films and the single grown GaN layers of the same thickness on sapphire. To further gain insight into the relation between the residual stress and the defects in the overgrown free-standing HVPE films, characterisation by scanning electron microscopy, atomic force microscopy and spatial resolved cathodoluminescence will be presented.

References:

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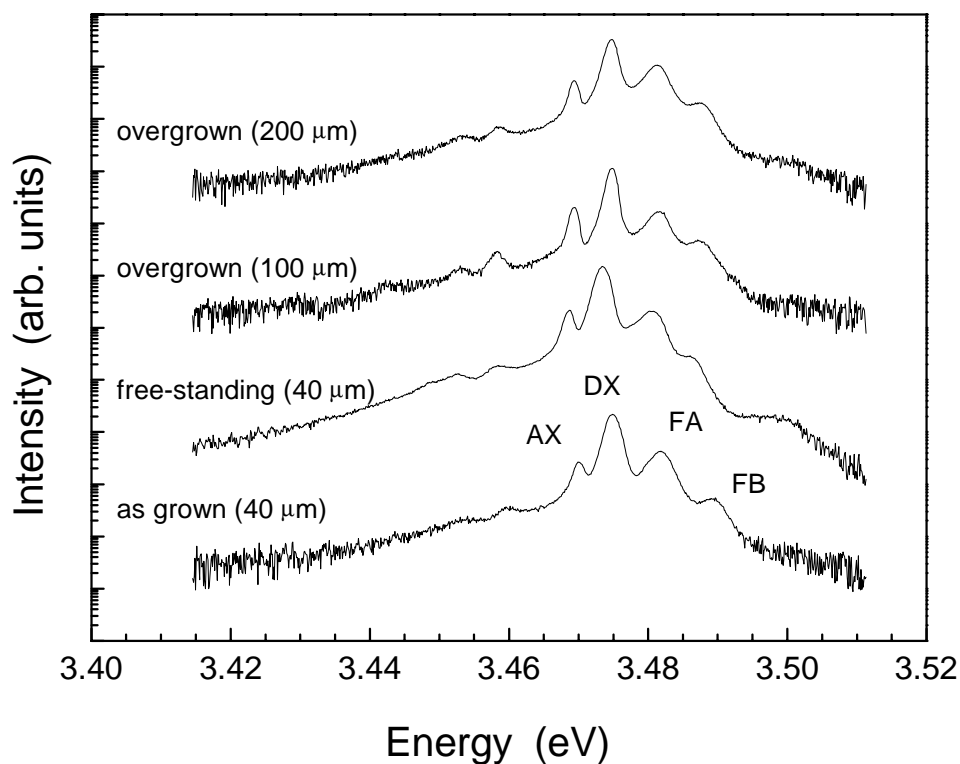


Fig.1 Low temperature (2K) photoluminescence spectra of thick HVPE-GaN films. (The excitation wavelength was 266 nm).